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ABSTRACT

China started to establish a national park system in 2015 for preserving integrity and authenticity of ecosystem and ensuring public welfare. To balance the two management objectives, refined conservation needs-based ecological compensation is supposed to be an effective measure with the support of an Environmental Decision Support System (EDSS). Based on literature review, this article proposes an exploratory framework of an EDSS with 2 modules for ecological compensation in China's national parks. Some potential calculation models are listed for synthesis of the system. Moreover, a set of potential indicators for conservation needs are proposed as the input of the EDSS.

KEYWORDS

National Park, ecological compensation, conservation needs, Environmental Decision Support System

INTRODUCTION

National parks are some of the most important protected areas around the world. International Union for Conservation of Nature (IUCN) lists national parks as the category II of protected areas (Dudley, 2008).

During the past 60 years, China has established more than 10 categories of protected areas (PA) with over 17% of its terrestrial areas (Zhang et al., 2016), but none of them is a national park yet. Management responsibilities of different PAs are delegated to different ministries or administrations. Unclear division of responsibilities caused conflicts and inconsistencies among multiple objectives (Zhang et al., 2016).

National park system is an approach to protect valuable ecosystems. In 2015, Chinese government announced *a Pilot Plan for Establishing National Park System*. Based on this pilot plan, national parks are required to consider conservation as a top priority mission in order to preserve authenticity and integrity of ecosystems, and in the meantime trying to achieve public welfare.

Paying high attention to public welfare means not only the whole society has the right to enjoy natural scenery with low-cost, but the development rights of indigenous communities living within and around the park should not be compromised by upgrading the conservation to an ecosystem scale. However, interests of the two types of stakeholders sometimes conflict. For example, Public Ecological Forests policy is widely applied in China. Although different provinces have different clauses in clarifying public ecological forests, it generally refers to forests, forest trees and forest land which are intended as their main function for ecological and social benefits and utilized mainly for the provision of public-welfare and social products or services. Due to the importance of the land's ecological safety, biodiversity protection, economic and social sustainable development, Chinese government has very strict regulation on resources consumption in Public Ecological Forests. However, some traditional activities are highly depended on consuming particular resources. Pine tree used for smoking black tea in Fujian province is such a case. Preservation and social development contradict in this case. Ecological compensation is incompatible with providing particular resources for communities while restricting human activities with negative externalities.

Numerous methods can be adopted to achieve these conflicting objectives. But no matter what measures we take, the processing of increasingly complex information which is essential to achieve the above objectives will be a challenge. The important question which needs being addressed is: *How can the government accurately identify the right target for* *compensation and optimize the objectives with lowest economic cost?* A Decision Support System (DSS) is a tool that can be employed to improve the decision making process, and optimize ecological compensation mechanism in China's national parks.

Indeed, varieties of Environmental Decision Support Systems (EDSS) exist around the world to support ecosystem or environmental management (McIntosh et al., 2011). But when it comes to ecological compensation issues, especially in national park context, it is hard to find existing EDSS-based solutions. Based on literature review, this article tries to propose an exploratory framework to address this gap.

LITERATURE REVIEW

In this section, we review the background of ecological compensation and national parks establishment in China, the necessity to establish a DSS-based ecological compensation mechanism, and also some categories of existing EDSS in related areas.

Ecological Compensation for National Parks

Ecological compensation is a unique term used in China, but there is a similar concept in the global context which is Payment for Ecosystem Services (PES). In this article, ecological compensation refers to human actions that try to achieve sustainably using ecological services by adjusting stakeholder interests with government or market oriented solutions. The value of ecological services and the cost of ecological protection and social development are the key elements in compensation (Li, 2013).

Ecological compensation originated in China in 1970s and 1980s. Despite the experiences in the past decades, it is still difficult to directly apply current ecological compensation mechanism in future national park context. There exist a few challenges including:

Defect with existing ecological compensation practices:

Since nearly all of the current ecological compensations are implemented with singular payment standard decided by governments, and regional differences in ecological conditions and social development cannot be reflected, over or under-estimated compensation failed to match conservation costs in many places, which weakened the anticipated incentives and conservation effectiveness (Sun, 2008).

Challenges posed by new requirements for managing future national parks:

The China's central government pointed out that the primary task for national parks is natural conservation, which is a general requirement for nearly all of the other protected areas. However, aimed at large scale conservation (Dudley, 2008), it is impractical and unnecessary to protect the national park as a no-go area. Meanwhile, since social welfare is one of the two key objectives for national parks, the contradiction between natural conservation and social development will be more obvious.

However, this is not a paradox beyond our capacity to cope with. By "refining conservation needs" in national parks, and taking targeted measures in ecological compensation, the challenges can be solved. For some areas with sensitive and low resilient resources, strict management approaches are necessary for the ecological security; while for those with lower protection priority and higher human-nature compatibility, reasonable resource utilization are permitted in line with conservation objective. This is what we mean by refined conservation needs.

The Necessity to Establish a DSS-based Ecological Compensation Mechanism

Refined conservation needs is an effective solution for ecological compensation challenges in national parks, but it also generates more complicated management information, increasing the difficulty in decision making. Decision Support System (DSS) is a tool that allows decision making to be more productive, agile, innovative, and/or reputable (Burstein, 2008).

There are multiple forms of DSS including model-driven DSS, data-driven DSS, communications-driven DSS, document-driven DSSs and knowledge-driven DSS (Burstein, 2008). And Environmental DSS (EDSS) is a managerial supporting tool for environmental policy makers to do trade-offs between environmental and social needs and development (McIntosh et al., 2011).

EDSS is often expected to be multi-objective or multi-criteria to deal with the complexity of the environment (Weng et al., 2010). Currently, there are four main technologies in EDSS: numerical calculation (models), geographical representation (GIS), artificial intelligence (optimization and decision analysis), and data management and networking (McIntosh et al., 2011).

Environmental Decision Support Systems

EDSS is a complicated synthesis involving different disciplines, such as Environmental Science, Ecology, Computer Science and Information Systems. In literature review, we investigate the areas that EDSS has been applied to and their functions.

Application of EDSS

We reviewed a series of EDSS, which revealed four main application categories in this area. They are: 1. The EDSS to monitor and simulate status of ecosystem components (Zhang et al., 2011, Twery et al., 2005, Casini et al., 2015); 2. The EDSS to model and predict effect of the risks to ecosystem (Mavsar et al., 2013, Zeng et al., 2007, Pierleoni et al., 2014, Zhang et al., 2015, Ortega et al., 2014); 3. The EDSS to compute and predict benefits from the ecosystem (Knieß et al., 2010, Bagstad et al., 2013, Tayyebi et al., 2016); 4. The EDSS to moderate and adjust relationships between human activates, the ecosystem, and natural resources (Weng et al., 2010, De Meyer et al., 2013).

Functions of EDSS

Since the numerical calculation is the most common technique in EDSS, we mainly focus on model-based EDSS, and list the main functions below. Simulation and optimization models can be embedded in EDSS. When facing a single problem or interrelated and complex issues, independent model or integrated model with multi-objectives and multi-criteria analysis methods can be employed (Kelly et al., 2013). In order to deal with different attributes of data, there are spatial or non-spatial analyses that can be used in EDSS. These functions are presented in the Appendix.

AN EXPLORATORY FRAMEWORK FOR AN EDSS TO BE USED IN THE ECOLOGICAL COMPENSATION IN NATIONAL PARKS

Although we presented several EDSS and models above, very few of them can be used directly to support ecological compensation in the context of China's national parks. The key challenges originate from the nature of ecological compensation itself. The literature review suggests there are many studies on EDSS-based ecosystem monitoring, simulating, and risk management, but limited research exists concerning the use of EDSS to balance human society development and ecosystem protection. With the aim of achieving integrity and authenticity of ecosystems, EDSS to be used in ecological compensation in national parks is expected to identify refined conservation needs and conduct simulation of the ecosystem under different human interference with the following capabilities:

- Compute and visualize conservation needs of a specific ecosystem under standardized instructions.
- Conduct scenario analysis with different human interferences.
- Provide multi-solutions with human-nature trade-off for decision makers to select.

However, almost none of the existing systems can meet these requirements. One way to overcome this limitation is to design a new and specialized EDSS.

The Proposed Exploratory Framework of EDSS

A reliable EDSS depends on a complete data set. For ecological compensation in national parks, two key aspects should be seriously considered: ecological conservation needs on authenticity and integrity, and community development demands. In this article, we tried to propose an exploratory framework of EDSS with two modules, just as indicated in Figure 1 and Figure 2. Module 1 is to identify conservation needs in national parks.

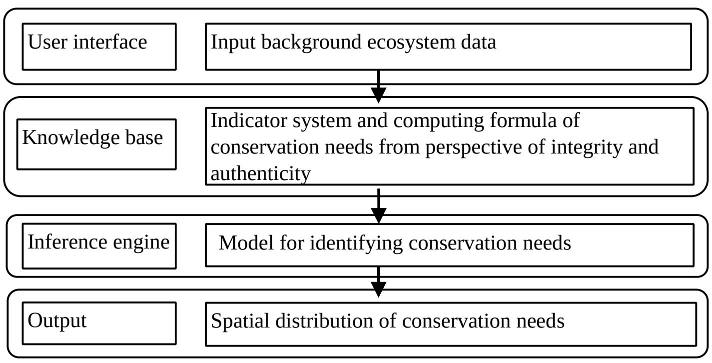

Figure 1. The module for identifying conservation needs in national parks

Although the key conservation objective of national parks is to maintain the intact and authenticity of ecosystem, there's no need to protect the whole region with strict restrictions. For some areas with sensitive and low resilient resources, strict management approaches are necessary for the ecological security; while for those with lower protection priority and higher human-nature compatibility, reasonable resources utilization are permitted in line with conservation objectives. Refined conservation needs are different from the methodology of function zoning in other protected areas. It is more specific and detailed in describing ecological status. It is also different from existing mythologies in quantifying conservation values. Since some high valued natural resources are keeping long-term good relationship with human society, and don't have high vulnerability, high conservation value doesn't equal to high conservation needs. Crested Ibis is such a rare species with high conservation value but highly depended on winter paddy fields created by human communities. From this perspective, different aspects of ecosystem need to be analyzed in order to develop targeted management solutions. Therefore, indicators and computing methods for refined conservation needs are the most important knowledge base for the EDSS in module 1.

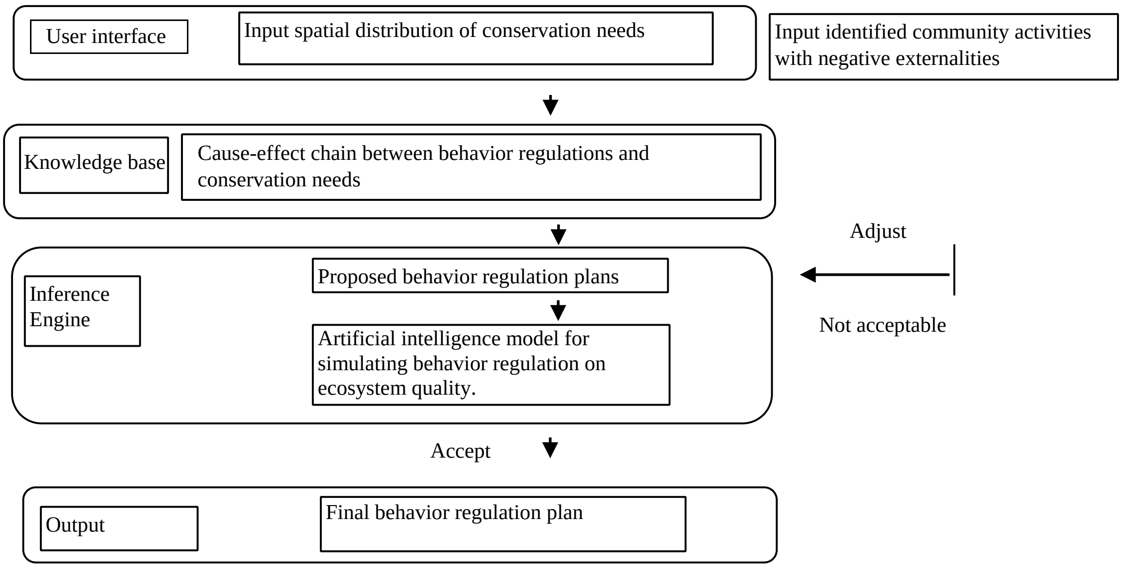

Figure 2. The module for simulating different scenarios of community development regulations

Module 2 is to simulate different scenarios of community development regulations. Based on the results collected in module 1, ecological compensation is supposed to only focus on some specific community activities which lead to high conservation needs, but not the whole community within and around the national park. Take the above mentioned black tea production as an example, the technical process of smoking with pine tree is only required to be changed or reduced in those areas with high conservation needs, but it is not necessary to prohibit all the tea making processes within the whole national park areas. But to what extend the human behaviors need to be regulated? With artificial intelligence model embedded in module 2, it is supposed to simulate different scenarios of internalizing negative externalities.

With the proposed EDSS, it is expected to help decision makers to select a more efficient management countermeasures, and to balance interests of different stakeholders with lower cost. In the near future, we will develop indicators to measure ecological conservation needs and input them into a GIS interface. We will also collect data from proposed national park pilot in China, trying to illustrate how to use the system in a real place.

RESEARCH AND POLICY IMPLICATIONS

This research is an exploratory work of connecting EDSS with ecological compensation in the context of China's national parks. It provides support for policy making in the following areas.

Identify key ecological problems needs to be solved

Unlike previous government oriented eco-compensation mechanisms in China, in module 1, we will develop indicators for quantitatively computing conservation needs in the future as the first step in developing the EDSS. Only the regions with high conservation needs require further analysis on human action regulations and compensation.

Target community activities with negative externality

Another technical issue is to determine what kind of activities should be regulated (activities with negative externality) in order to achieve ecological conservation objectives. Those high conservation needs and community density that have overlapped, and community activities that have negative impacts on ecosystems are the targets for regulation and compensation.

Decide to what extent human activities need to be regulated

There's no universal standard for compensation, but payment is highly dependent on community behavior regulation schemes. If we can decide to what extent human activities need to be regulated, payment amount can be calculated in specific cases. Combined with artificial intelligence techniques, the module 2 can be a tool to support scenario analysis and the selection of intervention measures, and is expected to lay foundation for further monetary calculation.

CONCLUSION

EDSS is supposed to be an efficient way to manage the complex information generated by the new compensation mechanisms in future national parks in China. Majority of existing EDSS are focused on some specific aspects of ecological or environmental protection, but they lack a comprehensive scheme for harmonious development of ecosystem and society. Based on literature review, this article proposed an exploratory framework of EDSS for ecological compensation in national parks for China which has two modules, one is for quantitatively identifying conservation needs and the other performs the regulation simulation and scenario analysis.

This article is not free from limitations. For instance, future research can investigate how different models can be combined as an intact system, how to develop indicators of conservation needs, and how to identify community behaviors that need to be regulated.

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APPENDIX: DIFFERENT FUNCTIONS OF EDSS

Model name	Category			Application area and reference
	To deal with dynamic and uncertainty	To deal with synthesis of problems	To deal with different data attributes	
AFFOREST-sDSS	Simulation & Optimization	Multi-objective method	Spatial analysis	Silvicultural regimes (Gilliams et al. 2005)
AVVIRK-2000	Simulation	Single objective	Non-spatial data analysis	Silvicultural regimes (Eid and Hobbelstad, 2000)
EFIMOD	Simulation	Single objective	Spatial analysis	Silvicultural regimes (Komarov et al. 2003)
EnerTree	Simulation & Optimization	Multi-criteria method	Spatial analysis	Forest residue recovery options (Röser et al. 2006)
Heureka	Simulation & Optimization	Multi-objective & multi-criteria method	Spatial analysis	Forest management plan (Korosuo, 2011)
MGC Larch	Simulation	Multi-objective & multi-criteria method	Non-spatial data analysis	Silvicultural scenarios (Pauwels et al. 2007)
SADfLOR	Simulation & Optimization	Multi-objective method	Non-spatial data analysis	Plan for landscape & forest (Garcia-Gonzalo, et al. 2013)
Forest Time Machine	Simulation	Multi-objective method	Spatial analysis	Forest management strategy (Andersson et al. 2005)
Geo-SIMA-HWIND	Simulation	Single objective	Spatial analysis	Wind damage assessment in forest (Zeng et al. 2007)
MOIRA	Simulation	Multi-criteria method	Non-spatial data analysis	Radionuclide contaminated aquatic ecosystem restoration (Ríos-Insua, et al. 2006)
Exp-DSS	Optimization	Single objective	Non-spatial data analysis	Manage contamination in marine ecosystems (Dagnino and Viarengo, 2014)
FICMDSS	Optimization	Single objective	Non-spatial data analysis	Water quality management (Zhang, et al. 2011)
SMC-DSS	Simulation & Optimization	Multi-objective & multi-criteria method	Non-spatial data analysis	Resources management and planning (Weng et al. 2010)
SmartScape™	Simulation	Multi-criteria method	Spatial analysis	Crop change scenario analysis (Tayyebi et al. 2016)
AIRS SDSS	Optimization	Multiple criteria analysis	Spatial data analysis	Sustainability assessment (Graymore et al. 2009)
SimBaT	Simulation & Optimization	Multi-objective method	Non-spatial data analysis	Water resource allocation (Pierleoni et al. 2014)
DESYCO	Simulation	Multiple criteria analysis	Spatial data analysis	Assess climate change impacts (Torresan et al. 2016)
TITIM GIS-tool	Simulation & Optimization	Multi-objective method	Spatial data analysis	Measure territorial impact of transport infrastructures (Ortega et al. 2014)
SDSS with MCDA-GIS integration	Optimization	Multiple criteria analysis	Spatial data analysis	Territorial & environmental evaluation (Massei et al. 2014)
SSDMM	Simulation & Optimization	Multiple criteria analysis	Non-spatial data analysis	Forest density management (Newton, 2012)